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ON ANTIMATTER PENETRATION INTO THE SOLAR SYSTEM AND THE EARTH'S ATMOSPHERE

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SUMMARY

The motion of hypothetical antibodies of the Solar system and in the atmosphere of the Earth is investigated. It is established that at collisions of antibodies with interplanetary gas and atmosphere atoms, not only annihilation but also intensive antibody evaporation takes place, its specific energy being by 10 orders less than the specific energy of annihilation. As a result, at 1 atom/cm^3 density of interplanetary gas, an antibody with radius $r_0 \leqslant 1$ cm, cannot cross the Solar system even once. At its entry into terrestrial atmosphere a sharp antibody deceleration takes place at the expense of the reactive pulsed radiation occurring at annihilation, as well as its evaporation, which will be completed for bodies of meteor dimension at altitudes of 450-800 km, and for $r_0 =$ = 1 m at 200 km altitude. Thus, any possibility of antimatter nature of meteors and comets, postulated in the work [1], is excluded.

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1. Lately papers appeared (for example [1]), where the question was discussed about the fact that part of comets and meteor bodies in cosmic dust, could consist of antimatter. However, the assumption of a possibility of existence in the Solar system of large amounts of antimatter with density $\rho_- = 10^{-22}$-10^{-24} g/cm^3 is highly questionable. It is still more doubtful that a considerable part of comets and meteors consists of antimatter.

The data of meteor and comet astronomy, as convincingly asserted by V.G. Fesenkov [2], speak against the existence of antibodies in the neighborhood of the Solar system. We shall bring forth a simple estimate, proving that, in a solid state, an antibody could not possibly even cross the Solar system, as on its path it will encounter interplanetary gas particles and will annihilate with them. We shall assume the average density of interplanetary gas as being 1 atom/cm^3 (which is clearly understated). Then on the path l from the Solar system boundaries to Earth, an antibody with head-on cross-section area <u>s</u>, will encounter ls atoms Every act of annihilation will induce an energy release ~ $9 \cdot 10^{20}$ ergs/g (estimated per unit of mass). At the same time the specific energy of evaporation (including heating up to evaporation temperature) for stony and iron meteorites is $8 \cdot 10^{10}$ ergs/g, i.e. by 10 orders less. Therefore, a single annihilation act will induce evaporation of ~ 10^{10} antibody atoms. If the body has the shape of a cylinder or prism of h_0 height and is not rotating (s = const), then the quantity of evaporated atoms over the path l will constitute $10^{10}\, ls$, and their mass will be

$$M \approx 10^{-14}\, ls. \tag{1}$$

Since the antibody mass $M_0 = h_0 s \delta$,

$$\frac{M}{M_0} \approx 10^{-14} \frac{l}{h_0 \delta}, \tag{2}$$

and if we postulate that the density of the body is $\delta = 3$ g/cm^3, $l = 6 \cdot 10^{14}$ cm, we shall obtain

$$\frac{M}{M_0} \approx h_0^{-1}, \tag{3}$$

i.e. an antibody of centimeter and less cannot cross the Solar system even once, from the Pluto-Earth orbit. If we assume that the antibody is spherical with initial radius r_0 and rapidly rotating, the result will not vary substantially. We have the evaporation equation

$$-dM = 10^{10} s \rho\, dl, \tag{4}$$

and inasmuch as $s \sim (M/\delta)^{2/3}$

$$-\frac{dM}{M^{2/3}} = 10^{10} \frac{\rho}{\delta^{2/3}}\, dl,$$

whence

$$M = \frac{10^{30}}{27} \frac{\rho^3}{\delta^2} l^3, \tag{5}$$

$$\frac{M}{M_0} \approx 10^{28} \left(\frac{\rho}{\delta}\right)^3 \left(\frac{l}{r_0}\right)^3. \tag{6}$$

In this case with $l = 6 \cdot 10^{14}$ cm and $\rho = 10^{-24}$ g/cm^3 we shall also obtain $M = M_0$ at $r_0 = 1$ cm, but the change of mass loss will follow the $M/M_0 \sim r_0^{-3}$ law.

If we take into account that the density of interplanetary gas near the Earth's orbit is by 2-3 order higher than that assumed by us, all the possibility of the existence in the Solar system of comets and meteor bodies of antimatter is excluded.

2. After investigating the rules of penetration of meteor bodies consisting of antimatter into the Earth's atmosphere, sharply differing from the rules of penetration by ordinary meteor bodies, it is possible to determine unilaterally, on the basis of actual meteor observations, the question on the percentage of meteor bodies consisting of antimatter.

Let us examine this plan in reality. An antibody of spherical shape, radius r_0 and density δ_0 penetrates vertically into the atmosphere.

Let us assume that the antibody moves at sufficiently high altitudes so that no shock wave is formed but only its collision with separate air molecules and atoms takes place. The mass of air molecules colliding with the antibody at the altitude H, is

$$dm = \pi r_0^2 \rho dH = \frac{s}{g} dp, \tag{7}$$

where $\rho = \rho(H)$ is the air density at the altitude H, $s = \pi r_0{}^2$, $\underline{p}$ is the pressure, $\underline{g}$ is the gravitation acceleration. As a result of annihilation, the antibody mass will be lost (so far the evaporation is neglected).

$$-dM = dm, \quad M_0 - M = m. \tag{8}$$

The pressure of the radiation field creates a reactive pulse dI, which, taking into account the distribution by angles, will be

$$dI = \frac{1}{3} c dm = -(M dv + v_0 dM). \tag{9}$$

Inasmuch as $v_0 << c$, one may neglect the second term of the first part of (9). Taking (8) into account, we have

$$dM = \frac{3dv}{c}(M_0 - m). \tag{10}$$

From (7), (8) and (10) it follows:

$$\frac{s}{g}dp = \frac{3dv}{c}(m - M_0) \tag{11}$$

and further

$$dp = \frac{3dv}{c}\left(p - \frac{gM_0}{s}\right). \tag{12}$$

Since $p \ll gM_0/s$, instead of (12) one may write

$$dp = -\frac{3dv}{c}\frac{gM_0}{s}. \tag{13}$$

Introducing the speed of sound $\omega^2 = dp/d\rho$, we reduce (13) to the form

$$d\rho = -\frac{3dv}{c\omega^2}\frac{gM_0}{s}. \tag{14}$$

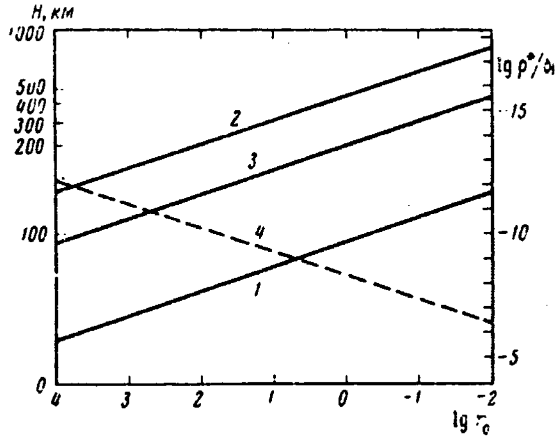
We integrate (14) in the density interval from zero to a certain critical value of ρ^* at which the antibody velocity $v^* = 0$, i.e. it will be completely decelerated by the reactive impulse of radiation. We shall obtain

$$\frac{\rho^*}{\delta} = \frac{4r_0 g v_0}{c\omega^2}. \tag{15}$$

Assuming that $v_0 = 60$ km/sec ($v_0/c = 2\cdot10^{-4}$), $g = 10^3$ cm/sec^2, $\omega^2 = 10^9$ cm^2/sec^2, we shall have

$$\frac{\rho^*}{\delta} \approx 10^{-9}r_0. \tag{16}$$

For bodies with $10^{-2} < r_0 < 5$ cm this condition corresponds to heights from 130 to 85 km of total deceleration. For bodies with $r_0 > 5$ cm, formation of a shock wave takes place, whereupon the boundary of the regime of continuous streamline flow rises with the increase of r_0 according to logarithmic law, reaching for bodies with $r_0 = 10^3$ cm the altitude of 120 km (see diagram). It is easy to show that from the instant of shock wave formation, the deceleration process accelerates by many times and is accomplished almost



Altitude of antibody destruction in the atmosphere as a function of its initial radius r_0:
1) total deceleration & expulsion
2) evaporation, 3) evaporation - taking shielding into account
4) boundary of shock wave formation

instantaneously at the expense of drawing a great air mass into motion.

Thus, the accounting of only the reactive deceleration by radiation at collisions with separate molecules leads at meteoric heights to a total deceleration of antibodies of indicated dimension, and then to their expulsion from the atmosphere, back into outer space.

3. However, half of the energy, released at annihilation, will be absorbed by the antibody and, as in the interplanetary space, this will result in its intensive evaporation. From the ratio 10^{10}: 1 of specific energies of annihilation and evaporation it follows that evaporating will be - the mass

$$-dM_1 = 10^{10}\,dm. \tag{17}$$

The evaporation equation will take the form

$$-dM_1 = 10^{10} s\rho\, dH, \tag{18}$$

and, inasmuch as

$$s \sim \left(\frac{M}{\delta}\right)^{2/3},$$

$$-\frac{dM_1}{M^{2/3}} = 10^{10}\frac{\rho}{\delta^{2/3}}\,dH, \tag{19}$$

or

$$-\frac{dM_1}{M^{2/3}} = 10^{10}\frac{1}{g\delta^{2/3}}\,dp = 10^{10}\frac{\omega^2}{g\delta^{2/3}}\,d\rho, \tag{20}$$

whence at antibody movement from the atmosphere limits to the level with density ρ^*, will be the evapored mass

$$M_1 = \frac{10^{30}}{27}\,\frac{\omega^6}{g^3\delta^2}\,\rho^{*3}, \tag{21}$$

$$\frac{M_1}{M_0} = 10^{23}\,\frac{\omega^6}{g^3 r_0^3}\left(\frac{\rho^*}{\delta}\right)^3. \tag{22}$$

The condition $M_1 = M_0$ (total evaporation) is reached at

$$\frac{\rho^*}{\delta} = 3\cdot 10^{-10}\frac{g}{\omega^2}\,r_0 = 3\cdot 10^{-16} r_0 \tag{23}$$

It corresponds for bodies with $r_0 = 10^2$, to the altitude of 200 km, and for those with $r_0 < 1$ cm to altitudes of 450-800 km (see diagram),

In connection with this let us make two remarks. The general evaporation equation of meteor physics will have the form

$$-dM_1 = \Lambda \frac{s\rho v^3}{2Q} dt, \tag{24}$$

where Q is the specific energy of evaporation (including the energy going for the body heating to the boiling point). Inasmuch as at vertical entry $dH = vdt$, formula (24) differs from formula (18), first, because instead of specific kinetic energy ratio to specific energy of evaporation ($v^2/2Q$), there stands in (18) the relation of specific energies of annihilation and evaporation (10^{10}), and, secondly, on account of absence in (18) of the heat transfer coefficient Λ, of which the basic part is the shielding factor $\underline{\alpha}$. With the evaporation at the expense of the energy of annihilation, the shielding by evaporated molecules will indeed play an essential role. Assuming that the shielding factor $\alpha \approx \Lambda \approx 10^{-2}$ (as at intensive evaporation of large meteor bodies), we could have lowered the limit of total evaporation to 200 km for bodies with $r_0 = 10^{-2}$ cm, and to 50 km for those with $r_0 = 10^2$ cm. However, one should not forget that the antimolecules are the only ones that will evaporate, and they should, in their turn, intensively annihilate with the incident atoms and molecules of the air. This is why the presence of the cloud of evaporated antibody molecules will not delay, but, on the contrary, will accelerate its destruction.

Opinions on a possible antimatter nature of Tungusska meteorite was also expressed in literature [3]. However, in order that the antibody may reach the altitude of 10 km (i.e. practically the ground surface), it is necessary that it have the dimensions of the largest among minor planets, which could not correspond to reality, inasmuch as this would lead to a much more significant catastrophe, that is, to the actual destruction of the Earth.

We shall still point to another series of considerations on the reasons why meteors (and therefore the comets, which are closely genetically connected with meteor streams), could not consist of antimatter.

1. As is shown by the spectra of bright meteors (including those pertaining to the streams), their glow is totally induced by the excitation processes of the evaporated atoms of a meteor body and does not represent any kind of peculiarities, pointing to the process of annihilation.

2. The antimatter meteor bodies producing the glow, observed in ordinary meteors, should have a very small mass (which according to [1], would be of the order of 10^{-10} g), and even in the absence of the expulsion effect and evaporation, they would be totally decelerated at the altitude of ~ 500 km.

3. According to the films taken with obturator, the investigation of the process of meteor deceleration allows us to determine their mass (regardless of the so called photometric masses, computed according to the glow equation). The mass of meteor bodies, determined by this method, exceeds by many orders that indicated in the [1].

A series of supplementary considerations versus the possibility of penetration into the Earth's surface of antimatter meteors is presented in the M. Subatowiez article [4], published after the writing of the present work. The ideas, close to the above-presented ones, are also included in the work [5].

As regards the effect, revealed by the authors of work [1], concerning the increase of gamma-rays and of neutron flow during the flight of meteors, it could possibly be real, but for their explanation other ways must be sought for.

*** THE END ***

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